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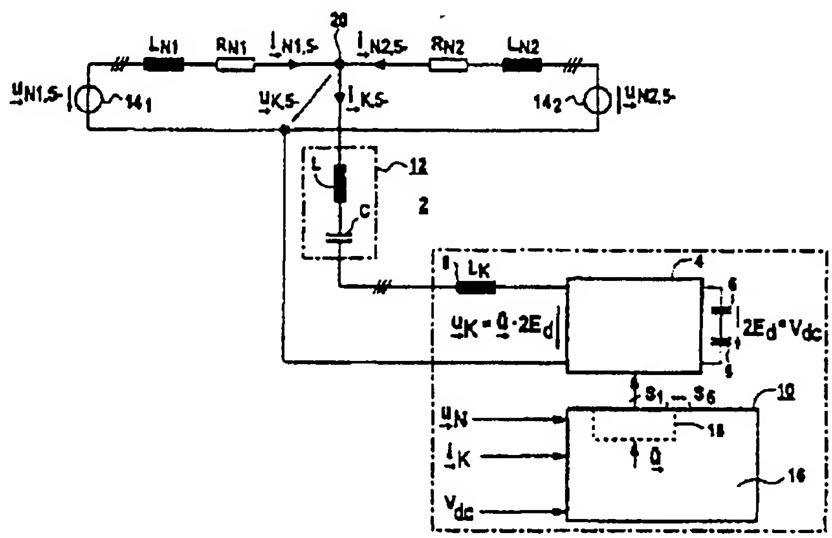
(54) **PROCEDE ET DISPOSITIF DE COMPENSATION DES DISTORSIONS DE LA TENSION DE RESEAU**

(54) **METHOD AND DEVICE FOR OFFSETTING NETWORK VOLTAGE DISTORTIONS**



(57) La présente invention se réfère à un procédé et à un dispositif de compensation de distorsions ($\underline{u}_{N,v\pm}$) de la tension de réseau (14), mettant en oeuvre un redresseur de courant pulsatoire (4) et un filtre actif (2) comprenant une couplage LC de circuits oscillants (12). Il convient, selon l'invention, de déterminer au moins une amplitude complexe ($\underline{u}_{N,v\pm}$) et au moins une distorsion de la tension du réseau ($\underline{u}_{N,v\pm}$), à partir de quoi un pointeur d'espace pour le rapport de transfert partiel ($\underline{a}_{v\pm}$) et un pointeur d'espace pour le rapport de transfert partiel ($\underline{a}_{h}$)

(57) The invention refers to a method and device for offsetting network voltage (14) distortions ($\underline{u}_{N,v\pm}$), involving a pulsating current rectifier (4) and an active filter (2) comprising a coupling device for LC oscillatory circuits. According to the invention, at least one complex amplitude ($\underline{u}_{N,v\pm}$) and at least one distortion of the network voltage ($\underline{u}_{N,v\pm}$), from which a space vector for the partial transfer ratio ($\underline{a}_{v\pm}$) and a space vector for the partial transfer ratio ($\underline{a}_{h}$) are determined depending on the real value of the transfer circuit voltage (V_{dc}) in the

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sont déterminés en fonction d'une valeur réelle de la tension du circuit intermédiaire (V_{dc}) du redresseur de courant pulsatoire (4), tandis que des signaux de commande (S_1,......, S_6) pour le redresseur de courant pulsatoire (4) sont formés sur la base d'un pointeur d'espace pour le rapport de transfert partiel (ü), obtenu à partir des pointeurs d'espace pour le rapport de transfert partiel ($\vec{ü}_{v\pm}$, $\vec{ü}_h$). De ce fait, le filtre actif (2) fait office, en un point de connexion (20) sur le réseau (14), de résistance complexe à faible impédance pour les harmonique supérieurs devant être atténués ($\vec{u}_{N,v\pm}$), et l'accumulateur capacitif (6) du redresseur de courant pulsatoire (4) est réglé sur une valeur nominale préétablie de la tension du circuit intermédiaire (V_{dcsoll}).

pulsating current rectifier (4), while control signals (S_1....., S_6) intended for the pulsating current rectifier are generated on the basis of a space vector for the partial transfer ratio (ü), obtained from the space vectors for the partial transfer ratio ($\vec{ü}_{v\pm}$, $\vec{ü}_h$). As a result, the active filter (2) operated, in on connecting point (20) on the network (14), as a complex low impedance resistor for higher harmonics to be mitigated ($\vec{u}_{N,v\pm}$), and the capacitive accumulator (6) in the pulsating current rectifier (4) is adjusted according to a set a nominal value for the transfer circuit voltage (V_{dcsoll}).

Description

Method And Device For Offsetting Voltage Distortions In A Network

The invention concerns a method and a device for offsetting voltage distortions occurring in a network by means of a pulsating current rectifier with a capacitive accumulator and an active filter comprising a coupling device for the LC oscillatory circuit.

To date, passive filters that have been tuned to the corresponding frequency to be filtered have been used to date for filtering harmonic oscillations. Due to the great improvement and price reduction of semiconductor power components, pulsating current rectifiers are increasingly developed and used as active filters. These either completely replace the passive filters or improve the characteristics of the passive filter installations (hybrid filters) in combination with passive filters. The advantage of active filters vis-à-vis passive filters can be seen especially therein that the filtering action of an active filter is infinitely variable and that active filters can protect themselves against overloads. They then work along their measuring limit. Moreover, any parallel or series resonances that may be present can be avoided by regulating with the network impedance. The properties of an active filter can be changed quite easily by changing the parameters of the regulating parameters in the case of a digital regulating system.

In the article "NEW TRENDS IN ACTIVE FILTERS" by H. Akagi, printed in the conference volume "EPE '95", Sevilla, pp. 0.017 to 0.026, the status of the active filter is introduced. This active filter can be connected in parallel to a load line or in series in a junction line between a network and a load. In the first case, the

reactive current portions in the load current are determined and drawn off at the feeding point of the load by means of the active filter, so that the network is relieved of the reactive currents. In the serial coupling of the active filter, network harmonic oscillations are offset in such a way that the load voltage is relieved of these network harmonic oscillations. Furthermore, combinations with an active filter and a passive filter each and a combination of two active filters with parallel and serial coupling devices are introduced. It can also be seen in this article that the active filter with a coupling device processes the network voltage instead of processing the load current when this active filter with a parallel coupling device is connected in a distribution system.

In the article "HYBRID-ACTIVE FILTERING OF HARMONIC CURRENTS IN POWER SYSTEMS, printed in "IEEE/PES Winter Meeting", 1995, pp. 1 to 7, the topology and the control of a hybrid filter is introduced which consists of a passive and an active filter. The active filter has a pulsating current rectifier with a capacitive accumulator that is connected to an alternating current network by means of a rectifier and a transformer. The pulsating current rectifier is switched electrically in series with the passive filter by means of a coupling transformer. The passive filter has several LC oscillatory circuits which are each tuned to a harmonic and whose impedance is capacitive. By means of the rectifier, the capacitive accumulator of the pulsating current rectifier is set to its nominal value. The load current, network voltage and filter voltage are used as input signals for the regulating and control device of the active filter. Various current portions of a nominal value of a filtering current are determined from these input signals, that are superimposed on the nominal value of the filtering current . The control signals for the pulsating current

rectifier of the active filter are generated by means of a current regulator at the inputs of which the ascertained nominal value of the filtering current and a measured real value of the filtering current are present.

A control method for an offsetting device with parallel coupling is known from the publication "Shunt-Connected Power Conditioner for Improvement of Power Quality in Distribution Networks", printed in "International Conference on Harmonic oscillations and Quality of Power", Las Vegas, Nevada, Oct. 16 - 18, 1996. It can be seen in this conference report that the space vector for the offsetting voltage is calculated from the voltage drop at the capacitive accumulator and a space vector for the transfer ratio. Moreover, it can be seen in this report that the space vector for the transfer ratio can be composed of several space vectors for partial ratios. It is furthermore noted how the space vectors are determined for the partial transfer ratio.

This offsetting device has a pulsating current rectifier with at least one capacitive accumulator, an adapter filter and a regulating and control device. This offsetting device is electrically shunted-connected to an imprefect consumer that is supplied by a network. A space vector for the network voltage, a space vector for the network current and a real value for the transfer circuit voltage that drops at the two capacitive accumulators of the pulsating current rectifier is fed to the regulating and control device. These space vectors are generated from measured conductor voltages and network currents by means of a space vector transforming device. The regulating and control device has a regulator for determining a space vector for the transfer ratio and a pulse-width modulator. The space vector for the transfer ratio is the regulated quantity of the pulsating

current rectifier which is converted into control signals for this pulse current rectifier by means of the pulse-width modulator.

So that the desired filtering action of the active filter begins, this active filter must work like a complex resistor with low impedance at the connecting point for the harmonic oscillations to be mitigated. For this purpose, the filter is used as a dip for the harmonic generator connected in the vicinity. It would be advantageous if the filter were to behave like an ohmic resistor and thus mitigate harmonic oscillations. This would avoid resonance effects between the filter and the network.

To obtain this, the active filter must detect the harmonic oscillations to be filtered in the network voltage in its connecting terminals and pick up a current in phase to the respective harmonic oscillations. The size of the current can then be set by varying the value of the ohmic resistor. In the ideal case, the active filter then forms a short circuit for the selected harmonic oscillations, so that the selected harmonic voltages become zero at the connecting point.

It is now the object of the invention to provide a method and a device for carrying out the method for an active filter in such a way that a voltage difference between network and pulsating current rectifier voltage drives a desired filtering current through a coupling device for LC oscillatory circuits in a stationary manner.

According to the invention, this object is solved with the features of claim 1 and claim 3, respectively.

By means of this method according to the invention, a space vector for the total transfer ratio is determined in such a way that the

voltage difference between network voltage and pulsating current rectifier voltage drives a desired filtering current through a coupling device for LC oscillatory circuits in a stationary manner. The space vector for the total transfer ratio is thereby composed of several space vectors for partial transfer ratios.

By means of a first space vector for a partial transfer ratio that is determined dependent on an ascertained complex amplitude of a network voltage distortion in the network, a pulsating current rectifier voltage is generated dependent on the real value of the transfer circuit voltage which drives a filtering current that allows a network voltage distortion in the network voltage to disappear by its voltage drop at the network impedances. Thus, the active filter acts like a short circuit for a network voltage distortion at the connecting point.

A distortion part is generated in the pulsating current rectifier voltage by means of the other space vector for the partial transfer ratio, said distortion part being equal to the network voltage distortion part that is determined from the difference between the network voltage and first harmonic of the network voltage. As a result, no undesirable distortion currents flow into the active filter, so that the entire power of the pulsating current rectifier is available for filtering preset network voltage distortions.

To save further current rectifier power, the coupling device for LC oscillatory circuits must keep the first harmonic of the network voltage away from the pulsating current rectifier and, at the same time, offer a low-ohmic coupling of the pulsating current rectifier for a network voltage distortion to be filtered. These properties are fulfilled by a coupling device for LC oscillatory circuits whose resonance frequency is, for example, not equal to the

frequency of the 5th harmonic but, for example, equal to the frequency of the 4th harmonic. In this way, the pulsating current rectifier is not significantly loaded with the first harmonic of the network voltage, so that almost its entire power is available for the harmonic filtering. Due to the tuning of the LC oscillatory circuit coupling, the entire impedance between pulsating current rectifier and network is inductive for a network voltage distortion to be filtered, so that the method is always stable.

In an advantageous method, a further space vector for a partial transfer ratio is determined which is in phase to the first harmonic of the filtering current when the circuit voltage of the pulsating current rectifier is too small and inversely phased when the circuit voltage is too large. This results in a first harmonic of the pulsating current rectifier voltage, by means of which power is supplied to or removed from the capacitive accumulator of the pulsating current rectifier. The intermediate circuit voltage is thus set to a preset nominal value, so that an additional power-supply device for the capacitive accumulator of the pulsating current rectifier can be omitted.

To further explain the method according to the invention for offsetting network voltage distortions in a network by means of an active filter, reference is made to the drawings in which an embodiment of the device for carrying out the method of the invention is schematically illustrated:

Fig. 1 shows a block diagram of an active filter according to the invention which has a pulsating current rectifier with a coupling device for LC oscillatory circuits,

Fig. 2 shows the structure of a regulator for generating an

overall space vector for a transfer ratio, whereby, in

Fig. 3 the block diagram of a network voltage distortion regulator of the regulator of Fig. 2 is shown,

Fig. 4 shows the block diagram of the network voltage distortion regulator according to Fig. 3 with a current-limiting device,

Fig. 5 shows the block diagram of a control device for preventing undesirable filtering currents of the regulating device according to Fig. 2, whereby

Fig. 6 shows a block diagram of a direct-current regulator of the regulating device of the pulsating current rectifier.

Fig. 1 shows a block diagram of an active filter 2 that has a pulsating current rectifier 4 with at least one capacitive accumulator 6, an adapter filter 8 and a regulating and control device 10. This pulsating current rectifier 4 is electrically shunt-connected by means of a LC oscillatory circuit coupling 12 in a larger network 14, for example, in a ring network. Only two network areas 14_1, 14_2 of this network 14 are shown in which several harmonic generators operate (not shown in greater detail). A space vector for the network voltage $\underrightarrow{u}_N$, a space vector for the filtering current $\underrightarrow{i}_K$ and a real value for the intermediate circuit voltage V_{dc} that drops at the two capacitive accumulators 6 of the pulsating current rectifier 4 are fed to the regulating and control device 10. These space vectors $\underrightarrow{u}_N$ and $\underrightarrow{i}_K$ are generated from measured conductor voltages and filtering currents by means of a space vector transfer device which is not shown in greater detail. The adapter filter 8 represented here as a substitute by an inductance L_x, whereas this adapter filter 8 is shown in detail in the aforementioned conference report from Las Vegas. The regulating and control device 10 has a regulator 16 for determining

a space vector for the overall transfer ratio $\underline{\ddot{u}}$ and a pulse-width modulator 18 which is shown by a broken line. The space vector for the overall transfer ratio $\underline{\ddot{u}}$ is the regulated quantity of the pulsating current rectifier 4 that is converted into control signals S_1, ..., S_6 for this pulsating current rectifier 4 by means of the pulse-width modulator 18.

The LC oscillatory circuit coupling 12 consists of a series connection of a choke coil L and a condenser C. To reduce the power output of the pulsating current rectifier 4, this LC oscillatory circuit coupling 12 must have the property that it works highly resistive for the first harmonic of the network voltage $\underline{u}_{N,1+}$ and low resistively for harmonic oscillations $\underline{u}_{N,\nu\pm}$ to be filtered. If, in addition, the integration of the reactive power of the first harmonic shift of this coupling circuit 12 is to be as slight as possible, then the LC oscillatory circuit must be tuned to the harmonic oscillations to be filtered. By way of example, Fig. 1 shows the circuit for an active filter that is to filter a harmonic of the 5th order in the network voltage $\underline{u}_N$. In the case of several harmonic oscillations to be filtered, it can be advantageous to shunt-connect several appropriately tuned LC oscillatory circuits. This LC oscillatory circuit coupling 12 is selected such in its resonance frequency that the overall impedance between pulsating current rectifier 4 and connecting point 20 in the network 14 is inductive for the 5th harmonic to be filtered. To obtain a further reduction in output of the pulsating current rectifier 4, the coupling 12 must keep the first harmonic of the network voltage $\underline{u}_{N,1+}$ distant from the pulsating current rectifier 4 and, at the same time, offer a low-resistive coupling of the pulsating current rectifier 4 for the harmonic oscillations $\underline{u}_{N,\nu\pm}$ to be filtered. In this way, the pulsating current rectifier 4 is

only slightly loaded with the first harmonic of the network voltage $u_{N,1+}$ and the full pulsating current rectifier output is available for filtering the harmonic oscillations. In practice, an IGBT two-point current rectifier having a direct-current circuit is used as pulsating current rectifier 4 due to the high available switching frequency. The purpose of the measured value detection, regulating device 16 and pulse-width modulator 18 is to generate the space vector for the overall transfer ratio $\underline{\ddot{u}}$ between the real value V_{dc} of the intermediate circuit voltage and the space vector $\underline{u}_K$ for the pulsating current rectifier output voltage. If the active filter 2 is to act as a dip for the harmonic oscillations in the network areas 14_1 and 14_2 with several harmonic generators $\underline{u}_N$ that are connected, but not shown in greater detail, then the only sensible control strategy is that the filter 2 does not filter a special load current but works like a low-resistive resistor at the connecting point 20 for the harmonic oscillations $\underline{u}_{N,v\pm}$.

It can be seen in Fig. 1 that network areas 14_1 and 14_2 of the network 14 can be found on both sides of the connecting point 20 which are each represented by network connection impedances R_{N1}, L_{N1} and R_{N2}, L_{N2} and affect the portions of a distortion voltage of the 5th order $\underline{u}_{N1,5-}$ and $\underline{u}_{N2,5-}$. The network 14 contains any number of harmonic generators desired which are also connected via network impedances and affect the distortion voltages $\underline{u}_{N1,5-}$ and $\underline{u}_{N2,5-}$. A filtering voltage $\underline{u}_{K,5-}$ results at the connection point 20. Since the active filter 2 sets, for example, for the filtering of the 5th harmonic, this active filter 2 is low-inductive for this 5th harmonic and highly ohmic for the other frequencies. The filtering current $\underline{i}_{K,5-}$ flows through the active filter 2, flowing in phase to the filtering voltage $\underline{u}_{K,5-}$ and is composed of the harmonic currents $\underline{i}_{N1,5-}$ and $\underline{i}_{N2,5-}$ contained in the network current and

according to the network impedances R_{N1}, L_{N1} and R_{N2}, L_{N2}. The active filter 2 that is equal to an ohmic resistance thus absorbs a part of the harmonic currents $\underrightarrow{i}_{N1,5-}$ and $\underrightarrow{i}_{N2,5-}$ occurring in the connected network 14, i.e. all the more the lower resistive this active filter 2 is. If the ohmic resistance of this active filter 2 is zero, then the harmonic voltage $\underrightarrow{u}_{N,5-}$ drops to zero volt at the connecting point 20 and the active filter 2 absorbs the maximum possible current. This active filter 2 thus forms a short circuit, for example, for the 5th harmonic at the connecting point 20.

The structure of the regulating device 16 is schematically illustrated in Fig. 2. This regulating device 16 has at least one network voltage distortion regulator 22, a control device 24 to prevent undesirable filtering currents $\underrightarrow{i}_{K,v\pm}$ and a direct-current regulator 26 whose outputs are connected with a summation point 28. The structure of the regulator 22 is shown in greater detail in Fig. 3 and Fig. 4, whereby the representation in Fig. 4 has, in addition, a current limiter. The structure of the control device 24 is shown in greater detail in Fig. 5 and the structure of the direct-current regulator 26 in Fig. 6. An ascertained space vector for the network voltage $\underrightarrow{u}_N$ is fed to the network voltage distortion regulator 22, also called a harmonic regulator. If this harmonic regulator 22 is designed as in Fig. 4, then a space vector for an ascertained filtering current $\underrightarrow{i}_K$ and an effective current rectifier value I_{max} is also fed, whereby these two signals $\underrightarrow{i}_K$ and I_{max} are shown by means of a broken line in this case. A space vector for the partial transfer ratio $\underrightarrow{ü}_{v\pm}$ is present at the output of this harmonic regulator 22. The index v with v= 5, 7, 11, ... represents the ordinal number of a harmonic, whereby the index + or - characterizes the co-system or counter system, respectivley. For the example shown in Fig. 1, v = 5, whereby this 5th harmonic

occurs in the counter system, so that - appears as the second index. The space vector for the partial transfer ratio $\vec{\ddot{u}}_{v\pm}$ is then $\ddot{u}_{5-}$. A space vector for the ascertained network voltage u_N and a real value for the intermediate circuit voltage V_{dc} is supplied to the control unit 24. There is also a space vector for the partial transfer ratio $\vec{\ddot{u}}_h$ at the output. The space vector $\vec{i}_K$ for the ascertained filtering current, the real value for the ascertained intermediate circuit voltages V_{dc} and a preset nominal value for the intermediate circuit voltage V_{dcsoll} is fed to the direct-current regulator 26. A space vector for a partial transfer ratio $\vec{\ddot{u}}_{dc}$ is also present at the output. These space vectors for the partial transfer ratio $\vec{\ddot{u}}_{v\pm}$, $\vec{\ddot{u}}_h$ and $\vec{\ddot{u}}_{dc}$ are added to form a space vector $\ddot{u}$ for the total transfer ratio by means of the summation point 28, from which control signals 2_1, ..., S_6 are subsequently generated for the pulsating current rectifier 4 with aid of the pulse-width modulator 18.

The structure of the harmonic regulator 22 is shown in greater detail in Fig. 3. This harmonic regulator 22 has an identification device 30 at the input end for determining a complex amplitude $\underline{u}_{N,v\pm}$ of a network voltage distortion $\vec{u}_{n,v\pm}$ present in the network 14 with a tandem-arranged I regulator 32 and electrically series-connected multipliers 34 and 36 at the output end. The identification device 30 has a complex multiplier 38 with tandem-arranged averaging device 40, whereby an input of this complex multiplier 38 is connected with an output of a unit vector former 42. The space vector for the network voltage $\vec{u}_N$ is present at the second input of this multiplier 38.

A complex amplitude $\underline{u}_{N,v\pm}$ of a vth network distortion voltage $u_{N,v\pm}$ is formed from the product present at the output of the multiplier 38

is formed by means of the averaging device 40 with respect to a network period T. There is a conjugated complex unit space vector e* at the output of the unit space vector component 42 that circulates with an angular frequency +vω in the co-system and with an angular frequency -vω in the counter system, wherein ω is the rotary frequency of the space vector for the first harmonic of the network voltage $U_{N,1+}$. The complex amplitude un $\underline{u}_{N,v\pm}$ of the corresponding network voltage distortion $u_{N,v\pm}$ is formed from the product of the space vector for the network voltage u_N and conjugated complex unit space vector e* by means of averaging via the network period T. The output signal of the I regulator 32 is multiplied by means of the multiplier 34 with an imaginary unit +j. The product present at the output of this multiplier 34 is multiplied with a unit space vector $\underset{\rightarrow}{e}$ by means of the tandem-arranged multiplier 36, that is present at the output of a further unit space vector component 44. The product of this multiplication is a space vector for the partial transfer ratio $\underset{\rightarrow}{ü}_{v\pm}$. The I regulator 32 then changes the quantity and the angle of the space vector for the partial transfer ratio $\underset{\rightarrow}{ü}_{v\pm}$ until the corresponding network voltage distortion $\underset{\rightarrow}{u}_{N,v\pm}$ of the v^{th} ordinal number is eliminated in the space vector for the network voltage $\underset{\rightarrow}{u}_N$.

The purpose of this harmonic regulator 22 is, first of all, to identify the amplitude of a network distortion $\underline{u}_{N,v\pm}$ from the network voltage $\underset{\rightarrow}{u}_N$ and to generate a corresponding space vector for the partial transfer ratio $\underset{\rightarrow}{ü}_{v\pm}$ that activates a filtering current $i_{K,v\pm}$ which allows the network voltage distortion $\underset{\rightarrow}{u}_{N,v\pm}$ in the network voltage $\underset{\rightarrow}{u}_N$ to disappear by its voltage drop in the network impedances R_{N1}, L_{N1} and R_2, L_{N2}. As a result, the active filter 2 acts like a short circuit for this distortion voltage $\underset{\rightarrow}{u}_{N,v\pm}$ at the connecting point 20. To identify a complex amplitude $\underline{u}_{N,v\pm}$ of a

distortion voltage $\underline{u}_{N,v\pm}$ present in the network 14, a discrete complex Fourier transformation that is realized in the identification device 30 is used. For this purpose, having regard to the representation shown in Fig. 1, the space vector for the network voltage $\underline{u}_N$ is multiplied with a conjugated complex unit space vector $\underline{e}$*, whose angular frequency is 5ω and then fed to a sliding mean value window. In the case of a co-system harmonic, the conjugated complex unit space vector e* must have the angular frequency -vω. The output signal of the I regulator 32 is turned by +90° (multiplication with +j) and multiplied with a unit space vector e rotating in the direction of the counter system and having the angular frequency -5ω. In the case of a co-system harmonic, the output signal of the I regulator must be turned by -90° (multiplication with -j) and multiplied with a unit space vector e rotating in the direction of the co-system and having an angular frequency +vω. The I regulator 32 changes its output until the counter system of the 5th order has disappeared in the space vector for the network voltage $\underline{u}_N$.

Fig. 4 shows the structure of a harmonic regulator 22 which is provided with a current-limiting device 46. This current-limiting device 46 has a current-regulating circuit 48, a multiplier 50 and a device 52 for forming a peak real value for a filtering current $\hat{i}_K$. The current regulating circuit 48 consists of a comparator 54 and a PI regulator 56 that is, on the one hand, limited at the output end and is connected with an input of the multiplier 50. The non-inverting input of this comparator 54, is connected with the output of the device 52, at the input of which a determined space vector for the filtering current $\underline{i}_K$ is produced. At the inverting input of the comparator 54, there is a peak nominal value for the filtering current $\hat{i}_{Ksoll}$ that is given in dependency on an

effective current value for the rectifier I_{max}. The device for forming the peak real value for the filtering current $\hat{i}_K$ has a quantity former 58 and an averaging unit 60 that is arranged in tandem with the quantity former 58. At the output of the comparator 54, there is a deviation of the peak real value $\hat{i}_K$ for the filtering current from its nominal value $\hat{i}_{Ksoll}$ from which a regulated quantity VP is generated by means of the PI regulator 56. This regulated quantity VP is multiplied with the output quantity of the I regulator 32 and supplied to an inverting input of a further comparator 62 to whose non-inverting input the output of the averaging unit 40 of the identification device 30 is connected and to whose output the input of the I regulator 32 is connected.

The I regulator 32 of the harmonic regulator 22 becomes a PI regulator as a result of the coupling of the current-limiting unit 46 shown. In the event of an overload, the counter coupling of the harmonic oscillations regulator 22 is increased by the controlled output VP until the pulsating current rectifier 4 works at its current limit. Thus, the active filter 2 in this type of operation always works as the minimal possible ohmic resistor. To prevent the regulated quantity VP from becoming negative, i.e. the counter coupling becomes a co-coupling, it is necessary to limit the PI regulator 46 downward to zero.

If the allowable current of the pulsating current rectifier i_K is not sufficient to eliminate a v^{th} harmonic $\underrightarrow{u}_{N,v\pm}$ in the space vector for the network voltage $\underrightarrow{u}_N$, then the current-limiting device 46 ensures that the filtering current $\underrightarrow{i}_{K,\pm}$ is in phase to the network voltage distortion $\underrightarrow{u}_{N,v\pm}$ and the pulsating current rectifier 4 always works at the current limit. In this case, the active filter 2 always works as the smallest possible ohmic resistor for the

harmonic oscillations to be mitigated at the connecting point 20. When there is more than one active harmonic oscillation to be filtered, a harmonic regulator 22 is required for each harmonic to be filtered that each calculate a space vector for a partial transfer ratio $\underrightarrow{\ddot{u}}_{v\pm}$ in the manner described here.

Fig. 5 shows the structure of the control device 24 which has a device 64 for forming a space vector for a first harmonic of the network voltage co-system $\underrightarrow{u}_{N,1+}$, a subtracter 66 and a multiplier 68 that is arranged in tandem to the subtracter 66. The determined space vector for the network voltage u_N is present at the input of the device 64 and also at the first input of the subtracter 66. The second input of hte multiplier 68 is connected with an output of a reciprocal component 70, at the input of which a determined real value for the intermediate circuit voltage V_{dc} is present. The space vector for the partial transfer ratio $\underrightarrow{\ddot{u}}_h$ is present at the output of this multiplier 68.

The device 64 for determing a space vector for the first harmonic of the network voltage co-system $\underrightarrow{u}_{N,1}$ has a complex multiplier 72 and 74, connected to one another by means of an averaging unit 76, at each input and output end. Moreover, two unit space vector formers 78 and 80 are present which each generate a space vector $\underrightarrow{e}^*$ and $\underrightarrow{e}$, that counterrotate with the same frequency ω. There is a space vector for the first harmonic of the network voltage co-system $\underrightarrow{u}_{N,1+}$ at the output of this device 64, that is subtracter from the network voltage space vector $\underrightarrow{u}_N$ by means of the subtracter 66. The result obtained is all distortion voltages $\underrightarrow{u}_{N,v\pm}$ present in the network voltage u_N. After multiplication with the reciprocal value of the real value for the intermediate circuit voltage V_{dc}, the space vector for the partial transfer ratio $\underrightarrow{\ddot{u}}_h$ results. This space

vector for the partial transfer ratio $\underline{\ddot{u}}_h$ produces the same distortion portion $\underline{u}_{K,\nu\pm}$ in the pulsating current rectifier output voltage $\underline{u}_K$, so that no undesirable distortion currents $\underline{i}_{K,\nu\pm}$ flow into the active filter 2. In this way, the active filter 2 is only acted upon with a desired filtering current $\underline{i}_{K,\nu\pm}$.

Fig. 6 shows the structure of the direct-current regulator 26 in greater detail. This direct-current regulator 26 has a device 82 for determining a space vector for the first harmonic of the filtering current co-system $\underline{i}_{K,1+}$ at the input end and, at the output end, two electrically shunt-connected multipliers 84 and 86. Moreover, this direct-current regulator 26 has a regulator circuit 88 for the intermediate circuit voltage 88 and a reciprocal component 90. The output of the regulator circuit for the intermediate circuit voltage 88 is connected with a second input of the multiplier 84, whereas the output of the reciprocal component 90 is connected with a second input of the multiplier 86. There is a space vector for the partial transfer ratio $\underline{\ddot{u}}_{dc}$ at the output of the multiplier 86.

The regulator circuit 88 for the intermediate circuit voltage consists of a comparator 92 and a PI regulator 94. The inverting input of the comparator 92 is connected with an output of a delay element 96 of the first order, at the input of which and at the input of the reciprocal component 90, the determined real value for the intermediate voltage V_{dc} is present. A preset nominal value for the intermediate circuit voltage V_{dcsoll} is present at the non-inverting input of the comparator 92.

The device 82 for determining a space vector for the first harmonic of the first harmonic of the filtering current co-system $\underline{i}_{K,1+}$ is

structured identical to the device 64 for determining a space vector for a first harmonic of the network voltage co-system $\underline{u}_{N,1+}$, so that no further details have to be provided at this point. This device 82 determines the first harmonic of the filtering current i_K that is primarily determined by the first harmonic of the network voltage $\underline{u}_{N,1+}$ and the impedance of the LC oscillatory circuit coupling 12 for the first harmonic.

The regulator circuit 88 for the intermediate circuit voltages compares the filtered real value for the intermediate circuit volt V_{dc} with its nominal value V_{dcsoll} and feeds the deviation Δv_{dc} to the PI regulator 94. To increase the real value for the intermediate circuit voltage V_{dc}, the pulsating current rectifier 4 must generate a first harmonic of the voltage $\underline{u}_{K,1+}$ in phase to the first harmonic of the current $\underline{i}_{K,1+}$ flowing through the LC oscillator circuit coupling 12. Since the first harmonic of the network voltage $\underline{u}_{N,1+}$ will be much greater than the first harmonic of the output voltage of the pulsating current rectifier $\underline{u}_{K,1-}$, the first harmonic of the current $\underline{i}_{K,1+}$ can first be considered as a current of a current source due to the LC oscillatory circuit coupling 12. The space vector for the first harmonic of the co-system of the filtering current $\underline{i}_{K,1+}$ is determined via a complex Fourier analysis similar to the space vector of the first harmonic of the co-system of the network voltage $\underline{u}_{N,1+}$ and then transformed back. After the retransformation, the space vector for the first harmonic of the co-system of the pulsating current rectifier output voltage $\underline{u}_{K,1+}$ is calculated by multiplying the output quantity V_{dcy} of the regulator circuit 88 of the intermediate circuit voltage with the space vector for the first harmonic of the co-system of the filtering current $\underline{i}_{K,1+}$ which, with the reciprocal value of the real value of the intermediate circuit voltage V_{dc}, results in the space vector

for the partial transfer ratio $\underrightarrow{\ddot{u}}_{dc}$.

If the real value for the intermediate circuit voltage V_{dc} now deviates from its nominal value V_{dcsoll}, then the space vector for the partial transfer ratio $\underrightarrow{\ddot{u}}_{dc}$ is generated which is in phase to the space vector for the first harmonic of the co-system of the filtering current $\underrightarrow{u}_{K,1+}$ when the real value of the intermediate circuit voltage V_{dc} is too small and inversely phased when the real value of the intermediate circuit voltage V_{dc} is too large. This results in a space vector for the first harmonic of the co-system of the pulsating current rectifier output voltage $\underrightarrow{u}_{K,1+}$, as a result of which energy is supplied or removed from the capacitive accumulator 6 and the real value V_{dc} of the intermediate circuit voltage is thereby set to a nominal value of an intermediate circuit voltage V_{dcsoll}.

By means of this method according to the invention for a pulsating current rectifier 4 of an active filter 2 having a LC oscillatory circuit coupling 12, it is attained that the active filter 2 operates like a complex resistor with low impedance for the harmonic oscillations to be mitigated at the connecting point 20, as a result of which this active filter 2 serves as dip for the harmonic generator connected in the vicinity. The active filter 2 thereby behaves like an ohmic resistor, as a result of which the harmonic oscillations are mitigated. Resonance effects between the active filter 2 and the network 14 can thus be avoided. This method according to the invention is not restricted to a pulsating current rectifier 4 of an active filter 2 with a coupling device for LC oscillatory circuits 12, but can also be easily applied to other coupling variants.

Patent Claims

1. Method for offsetting network voltage distortions ($\vec{u}_{N,v\pm}$) occurring in a network (14) by means of a pulsating current rectifier (4) with a capacitive accumulator (6) and an active filter (2) having a coupling device for LC oscillatory circuits (12), comprising the following procedural steps:

   a) determining at least one complex amplitude ($\underline{u}_{N,v\pm}$) of a network voltage distortion ($\vec{u}_{N,v\pm}$) present in the network (14),
   b) generating a space vector for a partial transfer ratio ($\vec{\ddot{u}}_{N,v\pm}$) in dependency on this determined complex amplitude ($\underline{u}_{N,v\pm}$) in such a way that it becomes zero,
   c) determining network voltage distortions ($\vec{u}_{N,v\pm}$) occurring in the network (14) in dependency on a determined voltage space vector ($\vec{u}_{N}$) and a space vector for a first harmonic of the co-system of the network voltage ($\vec{u}_{N,v\pm}$);
   d) determining a space vector for the partial transfer ratio ($\vec{\ddot{u}}_{h}$) in dependency on these network voltage distortions ($\vec{u}_{N,v\pm}$) and an intermediate circuit voltage (V_{dc}) of the pulsating current rectifier (4) and
   e) generating control signals (S_1, ..., S_6) for the pulsating current rectifier (4) from a space vector for the total transfer ratio ($\vec{\ddot{u}}$) formed from the space vectors for the partial transfer ratios ($\vec{\ddot{u}}_{v\pm}$, $\ddot{u}_{h}$).

2. Method according to claim 1, wherein

   f) a space vector for a first harmonic of the co-system of the filtering current ($\vec{i}_{K,1+}$) is determined from a

determined space vector ($\underset{\to}{i}_K$) for the filtering current,

g) an intermediate circuit voltage deviation (ΔV_{dc}) of a real value for an ascertained intermediate circuit voltage (V_{dc}) is determined from a preset nominal value of an intermediate circuit voltage (V_{dcsoll}),

h) a regulated quantity for the intermediate circuit (V_{dcy}) is generated in such a way that this determined intermediate circuit voltage deviation (ΔV_{dc}) becomes zero,

i) a space vector for a first harmony of a co-system of the pulsating current rectifier output ($\underset{\to}{u}_{K,1+}$) is determined by multiplying the space vector for a first harmonic of the co-system of the filtering current ($\underset{\to}{i}_{K,1+}$) with the intermediate circuit regulated quantity (V_{dcy}), and

j) a space vector for a partial transfer ratio ($\underset{\to}{ü}_{dc}$) is generated, that is superimposed over the space vector of the overall transfer ratio ($\underset{\to}{ü}$), in dependency on this space vector for a first harmonic of the co-system of the pulsating current rectifier output ($\underset{\to}{u}_{K,1+}$) and the nominal value of the intermediate circuit voltage (V_{dcsoll}).

3. Device for carrying out the method according to claim 1 for an active filter (2), that has a pulsating current rectifier (4) with a capacitive accumulator (6) and a regulating and control device (10) and a coupling device for LC oscillator circuits (12), wherein this regulating and control device (10) has a regulating device (16) for determining a space vector for the overall transfer ratio (ü) with a tandem-arranged pulse-width modulator (18), at whose outputs there are control signals (S_1, ... S_6) of the pulsating current rectifier (4) and wherein this regulating device (16) has at least one network voltage

distortion regulator (22) and a control device (24) for preventing undesirable filtering currents whose outputs are connected with a summation point (28) and at whose inputs there is a determined network voltage space vector ($\underrightarrow{u}_N$) in each case.

4. Device according to claim 3, wherein the regulating device (16) has a direct-current regulator (26) that is connected with the summation point (28) at the output end and at whose inputs there are a space vector for the determined filtering current ($\underrightarrow{i}_K$), a real value for the intermediate circuit voltage ascertained (V_{dc}) and a preset nominal value for the intermediate circuit voltage (V_{dcsoll}).

5. Device according to claim 3, wherein each network voltage distortion regulator (22) has an identitifcation device (30) at the input end for determining a complex amplitude ($\underline{u}_{N,v\pm}$), a network voltage distortion ($\underrightarrow{u}_{N,v\pm}$) present in the network with tandem-connected I regulator (32) and, at the output end, two series-connected multipliers (34, 36) that are tandem-connected to the I regulator (32), wherein an imaginary unit ($\pm j$) is present at every second input of the first multiplier (34) and a unit space vector (e) of the second multiplier (36) and wherein the network voltage space vector ($\underrightarrow{e}*$) and a conjugated complex unit space vector ($\underrightarrow{e}*$) are present at the inputs of the identification device (30), wherein the unit space vector ($\underrightarrow{e}*$, $\underrightarrow{e}$) counterrotates with the frequency (ω) of the network voltage distortion ($\underrightarrow{u}_{N,v\pm}$).

6. Device according to claim 3, wherein the control device (24) has a device (64) for determining a space vector for a first

harmonic of the co-system of the network voltage ($\vec{u}_{N,v\pm}$) that is arranged in tandem with a comparator (66) having a tandem-arranged multiplier (68), wherein there is a network voltage space vector ($\vec{u}_N$) at the input of the device (64) and at the non-inverting input of the comparator (66) and wherein the second input of the multiplier (68) is connected with an output of a reciprocal component (70) at whose input an intermediate circuit voltage real value (V_{dc}) is present.

7. Device according to claim 4, wherein the direct-current regulator (26) has a device (82) for determining a space vector for a first harmonic of the co-system of the filtering current ($\vec{i}_{K,v\pm}$) which is arranged in tandem with the multiplier (84) and an intermediate circuit voltage regulator circuit (88) and, at the output end, a multiplier (86) whose second input is connected with an output of a reciprocal component (90) and wherein the output of the intermediate circuit voltage regulator circuit (88) is connected with the second input of the tandem-arranged multiplier (84).

8. Device according to claim 6 or 7, whrein the device (64, 82) for determining a space vector for a first harmonic of the co-system ($\vec{u}_{N,v\pm}$, $\vec{i}_{K,v\pm}$) has an identification device for determining a complex amplitude ($\underline{u}_{N,1+}$, $\underline{i}_{K,1+}$) of a space vector for a first harmonic of the co-system ($\vec{u}_{N,1+}$, $\vec{i}_{K,1+}$) with a tandem-arranged multiplier (74), wherein a determined space vector ($\vec{u}_N$, $\vec{i}_K$) and a conjugated complex unit space vector ($\vec{e}^*$) are present at the inputs of the identification unit and a unit space vector ($\vec{e}$) at the second input of the multiplier (74), wherein these unit space vectors ($\vec{e}^*$, $\vec{e}$) counterrotate with the first harmonic of the frequency (ω) of the

ascertained space vectors ($\underline{u}_N$, $\underline{i}_K$).

9. Device according to claim 5 or 8, wherein a complex multiplier (38, 72) having tandem-arranged averaging units (40, 76) are provided as identification device (30), wherein an ascertained space vector ($\underline{u}_N$, $\underline{i}_K$) and a conjugated complex unit space vector ($\underline{e}^*$) are present at the inputs of the complex multiplier (38, 72).

10. Device according to claim 7, wherein a delay element (96) of the first order is placed in front of the intermediate circuit voltage regulator circuit (88) and said regulator circuit (88) having a PI regulator (94) which is connected at the input end with an output of a comparator (92) whose inverting input is connected with the output of this delay element (96) and wherein an ascertained real value for this intermediate circuit voltage (V_{dc}) is present at the input of this delay element (96) and a preset nominal value for the intermediate circuit voltage (V_{dcsoll}) at the non-inverting input of the comparator (92).

11. Device according to claim 3, wherein a microprocessor is provided as regulating device (16).

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Ottawa, Canada
Patent Agents

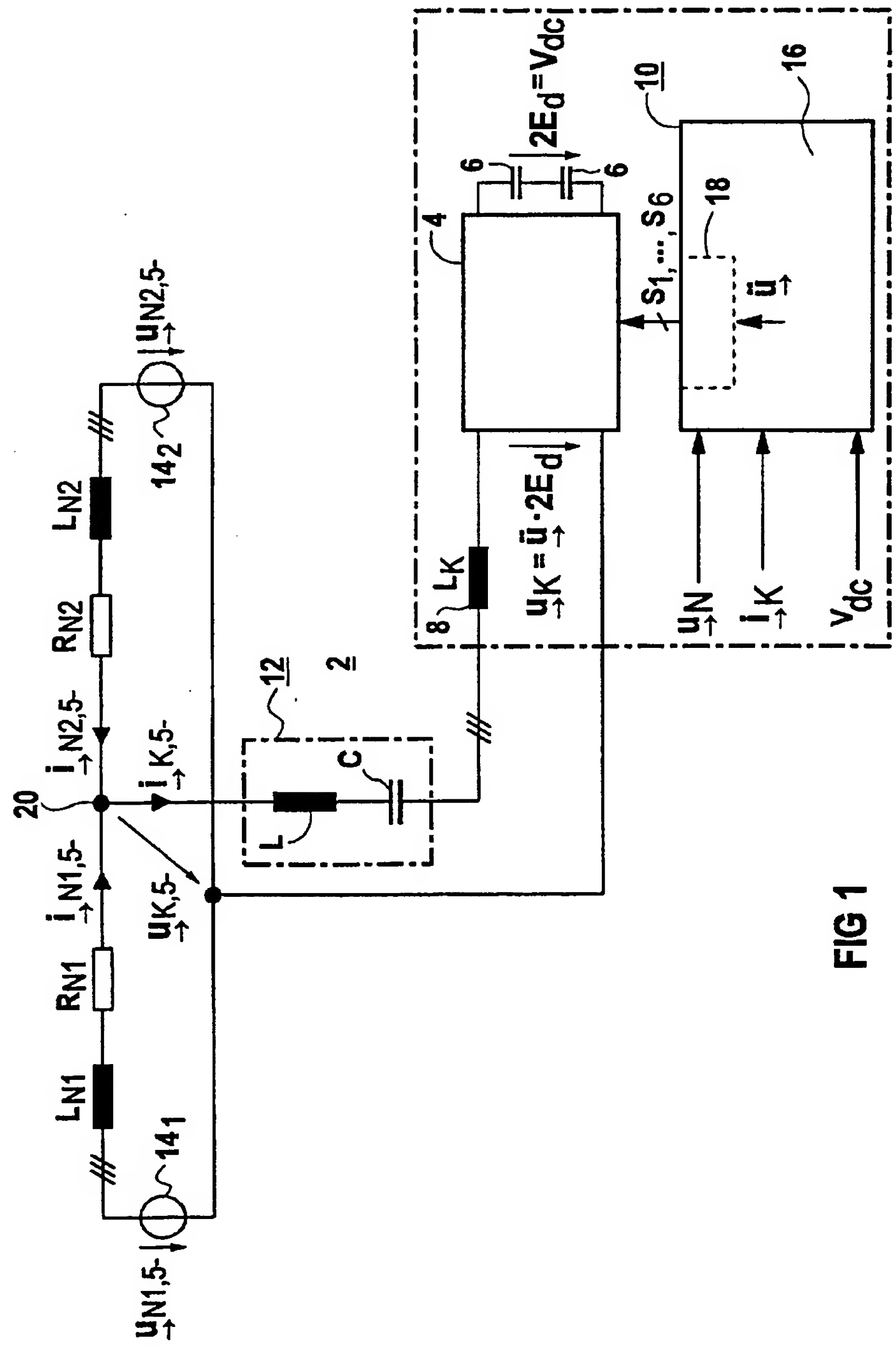

$u_{N1,5-}$
14_1
L_{N1}
R_{N1}
$i_{N1,5-}$
$u_{K,5-}$
20
$i_{K,5-}$
$i_{N2,5-}$
R_{N2}
L_{N2}
14_2
$u_{N2,5-}$
L
C
12
2
8
L_K
$u_K = \ddot{u} \cdot 2E_d$
4
6
6
$2E_d = V_{dc}$
$S_1, \ldots, S_6$
18
$\ddot{u}$
10
16
u_N
i_K
V_{dc}

FIG 1

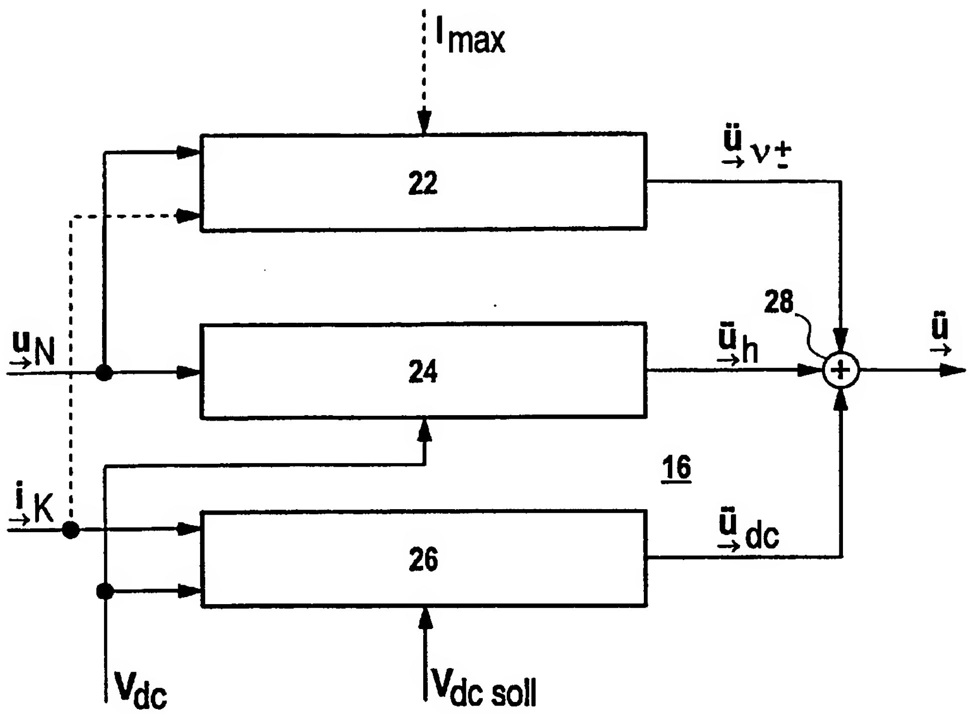


FIG 2

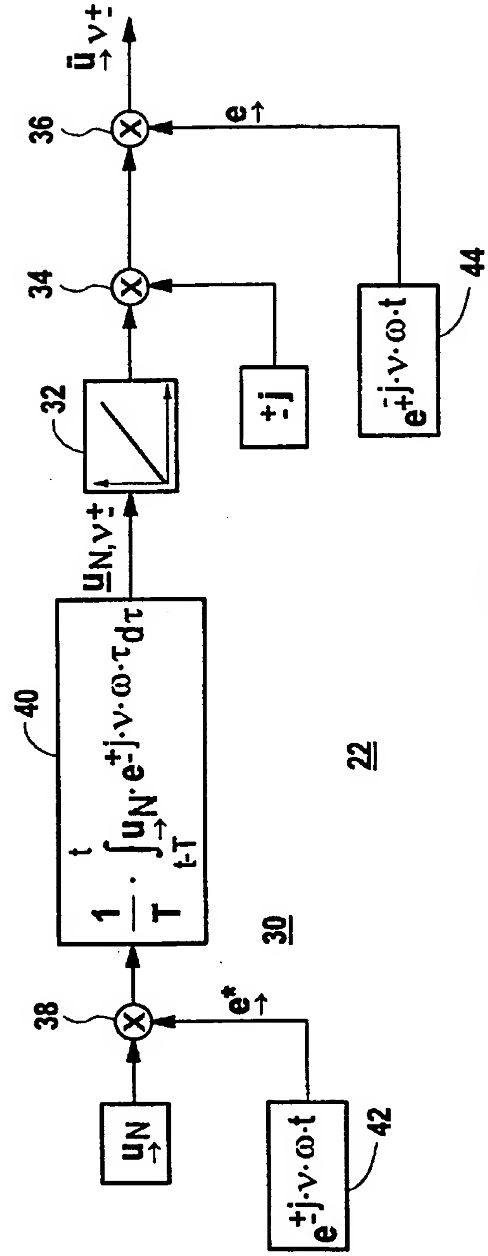


FIG 3

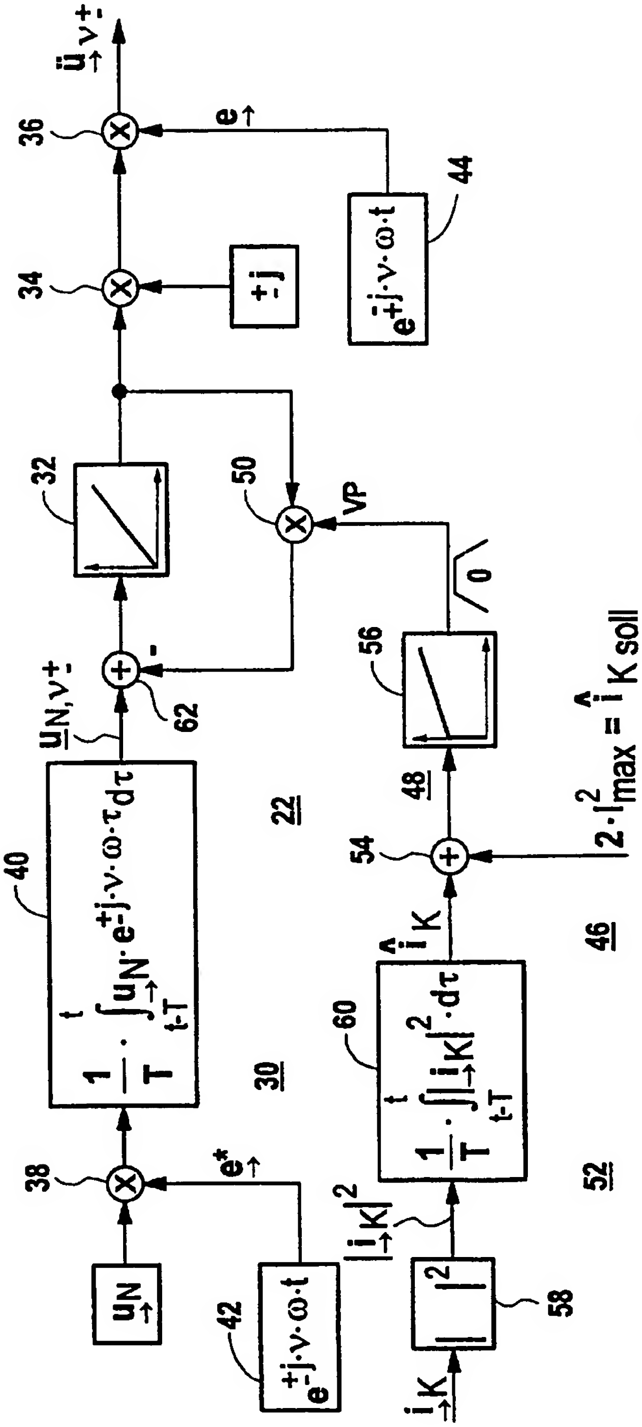


FIG 4

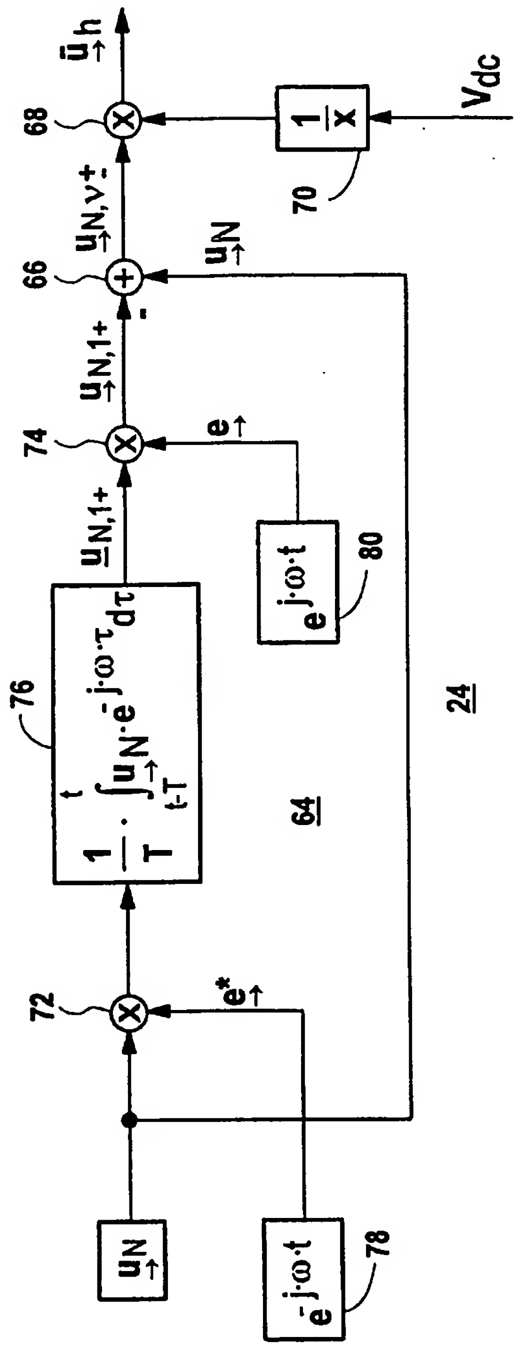
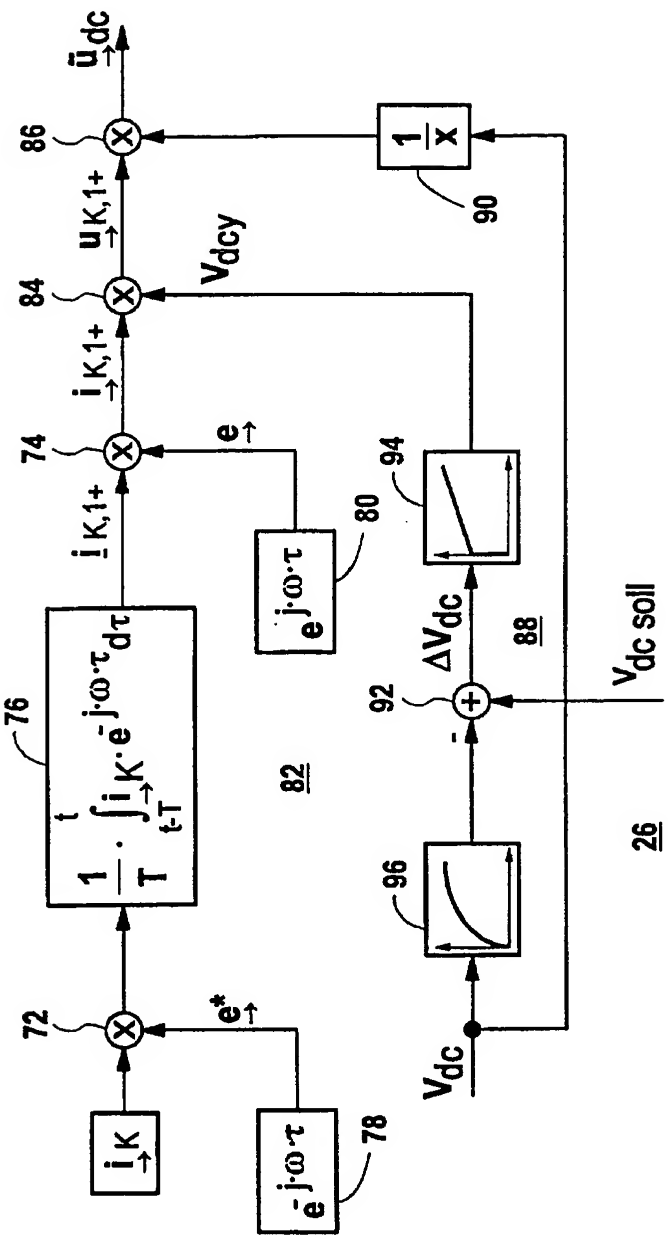


FIG 5



72
74
76
78
80
82
84
86
88
90
92
94
96
26
e*
e
1/x
ΔVdc
Vdcy
Vdc
Vdc soll

FIG 6